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Have Past Foresight exercises been able to correctly indicate future directions?

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1 Introduction

In Japan, foresight exercises have been conducted every five years since 1971, to gain perspectives on future trends in science and technology in view of the coming thirty years. The National Institute of Science and Technology Policy (NISTEP) has been responsible for the task since the fifth Foresight , and has extended the objectives to provide the future outlook of science and technology as well as the future society surrounding it, and in recent years added the grasping of social needs and the drawing up of future scenarios. The latest exercise in FY 2009, "The 9th Foresight : Contribution of Science and Technology to Future Society," was conducted with a picture of the future direction to pursue borne in mind, whereby the focus of discussion was placed on methods to overcome the global and national issues that may arise in the future .

The exercise included: a questionnaire for experts, on the development of science and technology; a scenario of people's lives in the future, and a framework and paths that would lead to such a scenario; and workshops to enable discussion on each region's sustainable development and its enabling technologies. The results were compiled into a three-volume report.[1]

The questionnaire for experts (Delphi survey) has been conducted from the first Foresight to the latest, with no exceptions, enabling us to evaluate the reliability of the predictions, i.e., the level of attainment viewed from the present perspective.

The predictions from the first Delphi survey, which was published in 1971, to the fifth (published more than twenty years after the 1st, in 1992) have been assessed by groups of experts. As Japan is the only country in the world that has carried out uninterrupted surveys of this kind, it has the unique opportunity to examine the wisdom of the past, and the surveys may be considered as a valuable soft-asset from a global perspective.

An announcement of the survey evokes an interest in how many of the past predictions have been realized and to what degree. This report presents an overview of the realization assessment covering the predictions of the first to fifth surveys, and gives an account of some science and technology that has been realized and some that has not come to fruition.

2 The Method for Assessing the Realization Status

The questionnaire, for experts, on individual fields of science and technology is named after the method employed, and hence is called the Delphi survey. The Delphi method is to implement two or more rounds of the same questionnaire for a group of experts, until the answers converge towards some concrete opinion. In the second and subsequent rounds, summary results of the previous round are shown to the respondents, and they are encouraged to review their early answers in light of the trends of the overall opinions. As some respondents modify their views and adopt the mainstream ideas, the overall opinion tends to converge (Table 1). The Delphi method is considered to be one of the effective methods for long-term foresight, which has to depend more or less on intuition.

Delphi surveys thus far conducted in Japan have included two rounds of the questionnaire for the purpose of gathering experts' opinions on future science and technology ("topics" in this report) in terms of the importance, feasibility, and the approach to be taken for realization. In the fifth Delphi survey, an evaluation of the results of the first Delphi survey

was implemented in order to assess the realization status. Thus, one previous survey has been added at the time of each Delphi survey since the fifth one.

A summary of the five previous Delphi surveys , whose realization statuses were assessed in the ninth Delphi survey, is shown in Table 2. From the first to the fifth survey, the number of topics taken up became larger and larger, as did the number of respondents. Also, topics concerning the fundamental aspects of science and technology have gradually become included in the surveys, in addition to the technologies of significance in view of social applications.

The work for the realization status assessment carried out in the ninth Delphi survey was allotted to twelve panels, which were organized for the ninth survey. Preliminary counseling decided that the levels of realization of these topics should be classified, based on the evaluation from the viewpoint at the time of assessment, into the following three levels: "fully realized," "partially realized," and "not realized." Partial realization includes cases where some of the contents of the topic have been realized and cases where the results open to consideration show that realization has been reached from some viewpoints, but not from all. For the topics judged as "not realized," the reasons for no realization were also discussed. Although the survey results include information on the expected year of realization, there are cases where pinpointing the precise period of realization is difficult. Therefore, a comparison of the years of expected and actual realization was not performed.

3 Overview of Realization Status Assessment

The following is an overview of the realization status as of the time when the ninth Delphi survey was conducted. Further details can be found in the reference materials of the ninth Delphi Survey Report.[1]

3-1 Ratio of Realization

The assessment indicates that around 70 percent of the topics given in the first through fifth surveys have been realized (including partial realization) (the number of realized topics / the total number of target topics). The ratio of exact realization increases with time. However, the ratio for the other 30 percent of topics does not increase with time, indicating that it is impossible to realize these topics in the time span of tens of years, or that they have become obsolete or meaningless over time.

Field-by-field examination indicates that the fields directly related to human life (e.g., environment,

Table 1 : An Example of a Delphi Survey Summary Sheet

*The pentagons in the table represent the middle one-half of responses on the time of realization (the left edge, central apex, and right edge represent the 1/4, 1/2, and 3/4 accumulation points of the responses, respectively, arranged in order of forecasted year of realization [from early to later]). The hatched pentagon represents the results of the second round of the questionnaire, indicating a converging tendency of the opinions (i.e. narrower width than the non-hatched pentagon, which represents the first round). The apex of the shape (i.e. the halfway point of the accumulated responses arranged in order of realization year — from earlier to later years — is used as the value representing the year of realization.

Classification	Topic number	Topic	Questionaire	Number of respondents	Forecasted time of technological realization (The period when the topic will be realized somewhere in the world)								Forecasted timeof social realization (The period when the topic will become applicable/widely used in Japan)							Main organization/sector that promotes social realization (left columns)					
					Has already been realized	2011 - 2015	2016 - 2020	2021 - 2030	2031 - 2040	2041 or later	Not realizable (%)	I don't know	2011- 2015	2016 - 2020	2021 - 2030	2031 - 2040	2041 or later	Not realizable (%)	I don't know	University (%)	Public research organization	Private enterprise (NPO included)	Government (local government included)	Alliance of multiple fields	Others (ex. International organization)
Mechatronics	65	A supporting robot for human lives and activities (such as nursing care and domestic affairs) in general households.	1	165							0	1						0	2	23	27	72	21	36	3
			2	145							0	1						0	2	15	23	80	16	33	1
			Expert	12							0	0						0	8	33	33	92	0	25	0
	66	Autonomous robots with a judgment function that is capable of coping with complicated situations, such as production process work with process changes or situations like farm work	1	143							0	3						0	4	24	27	77	16	32	1
			2	127							0	2						1	3	20	26	84	10	28	2
			Expert	11							0	0						0	0	36	36	91	0	9	0

Source: Reference[1]

Table 2 : Implementation Summary: First to Fifth Delphi Survey

Survey No. (year)	Area under investigation	Time scope (30 years)	Number of topics	Questionnaire responses
1st (1971)	(1) Social development (enhancement of living standards [clothing, food, and housing], leisure, urb an development, (2) Information, (3) Medical insurance, (4) Food and agriculture, (5) Industry and resources (exploitation/ development of space/ocean/energy/resources, upgrading of mining and manufacturing, development of new materials).	Up until 2000	644	2482
2nd (1977)	(1) Resources and energy (food/forest/water resources and energy), (2) Environment and safety (environment and safety), (3) Family life and education (domestic life, leisure, and education), (4) Health (health care, medical care, and labor), (5) National land-use (transport, information and construction), (6) Industrial manufacturing, (7) Advanced/fundamental science and technology (space/marine exploratation, life science, and soft science).	Up until 2005	656	1316
3rd (1982)	(1) Energy and mineral/water resources, (2) Agricultural/forestry resources, (3) Life and education, (4) Environment and safety, (5) Health/medical care, (6) Life science, (7) Cities, construction, and civil engineering, (8) Traffic and transportation, (9) Communication, information, and electronics, (10) Space, (11) Marine science, (12) Materials and devices, (13) Manufacturing and labor.	Up until 2010	800	1727
4th (1987)	(1) Material, and processing, (2) Information, electronics, and software, (3) Life science, (4) Space, (5) Marine science, (6) Earth science, (7) Agriculture, forestry, and fishery, (8) Mineral/water resources, (9) Energy, (10) Manufacturing and labor, (11) Health/medical care, (12) Life, education, and culture, (13) Transportation, (14) Communication, (15) City and construction, (16) Environment, (17) Safety.	Up until 2015	1071	2007
5th (1992)	(1) Material and processing, (2) Information and electronics, (3) Life science, (4) Space, (5) Elementary particles, (6) Marine/earth sciences, (7) Mineral/water resources, (8) Energy, (9) Environment, (10) Agriculture, forestry, and fishery, (11) Manufacturing, (12) Cities, construction, and civil engineering, (13) Communication, (14) Traffic, (15) Health/medical care, (16) Social life.	Up until 2020	1149	2385

Source: Reference[1]

security, health care, medicine, and life science) have a relatively high score in terms of the realization and partial realization rate. The ICT field shows a high score for the exact realization ratio (excluding partial realization). On the other hand, the fields related to transport and energy show low ratios of realization. As a general tendency, those topics that were expected for early realization scored high realization ratios, and those with a lower degree of importance generally show low realization ratios. Note, however, that there have been some cases where topics with low importance were realized, notably in the in ICT field.

3-2 Reasons for No Realization of a Topic

Inspecting the reasons for no realization of a topic, technical problems are by and large the most frequent causes.

In the first and second surveys, where many of the topics involved social aspects, a relatively large portion of the reasons for no realization was occupied by social problems and insufficient needs. However, each time the survey was conducted, the proportion of technical problems cited as the obstacle to realization has become progressively larger.

As viewed on a field-by-field basis, technical problems have been cited as the reason for no realization in more than 75 percent of topics related to medical and health care through the first to fifth surveys. Cost is one of the major problems, in addition to technical problems, in infrastructure-related domains, such as resources and energy, transport, construction and civil engineering, and the frontier domains, such as space and marine. Cost is the most frequently cited obstacle in some cases. The advent of alternative technology is also pointed out as the obstacle more often in fields related to ICT or electronics (especially in communication field) than in other fields. In the fourth and fifth surveys, among the topics that failed to be realized, for around 30 percent of them, the advent of an alternative technology was stated as the reason for no realization.

As an example, the obstacles to realization of the topics in the fifth survey, are shown for each field in Figure 2. Among the 100 most important topics that were predicted to be realized by 2009, some of them still remain unrealized, and the reasons why are listed in Table 3.

4 Examples: Realized and Unrealized topics

This section introduces selected examples of realized and unrealized topics listed through the first to fifth survey. The characteristics of the Delphi survey and subsequent developments of the topics are also described. Note that the "partially realized" cases are included in the description of the realized topics.

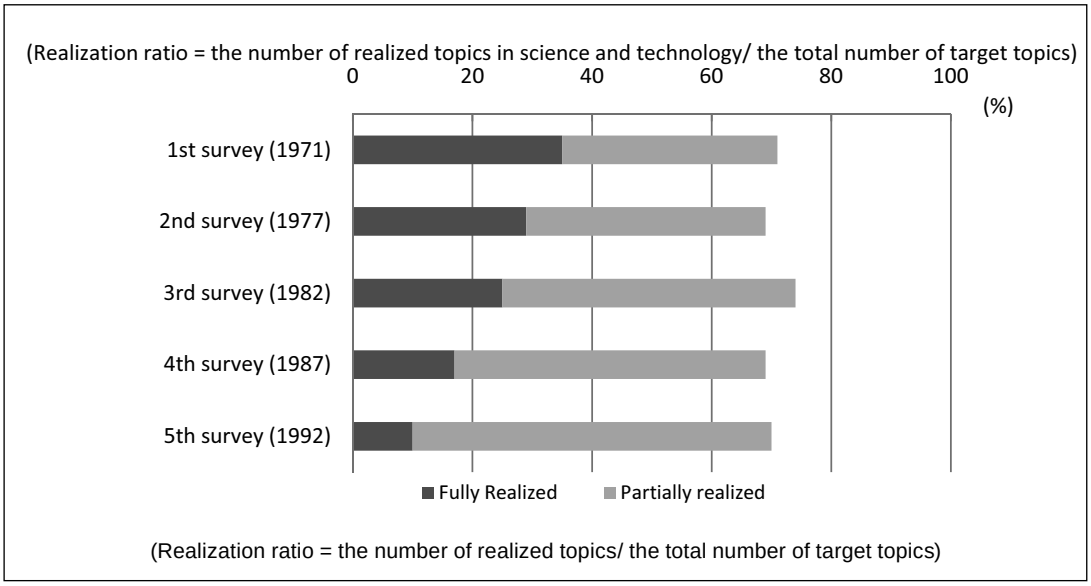

Figure 1 : Outcomes From First to Fifth Delphi Surveys: Realization Ratio

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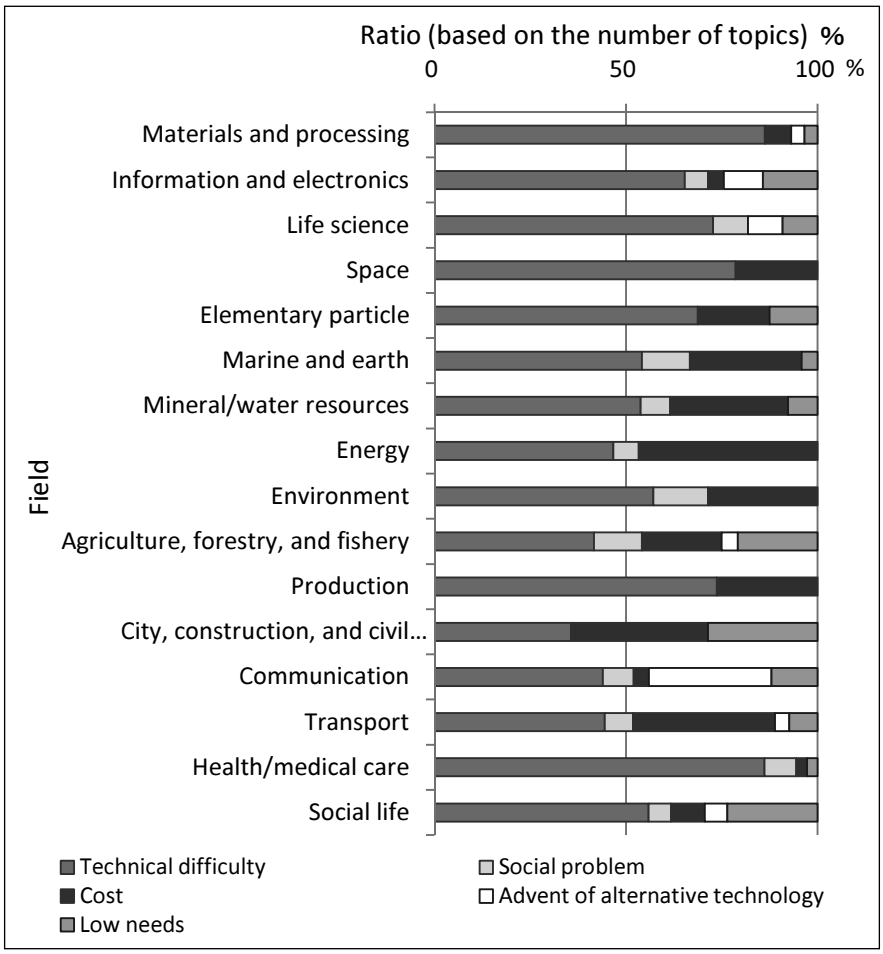

Figure 2 : Ratio of Reasons for No Realization of a Topic (5th survey)

Source: References[1]

Table 3 : Examples of Unrealized Topics in: (Those Predicted to Be Realized by 2009 in the 5th Delphi Survey)

Field	Topic	Predicted year of realization	Reason for no realization
Communication	Practical use of long-distance, large-capacity optical communication methods, ulitizing optical fibers and coherent optical communication technology (e.g. the optical hetrodyne method).	1999	Technical difficulty
Marine and Earth	Founding of an educational organization for earth-science research in the broad sense of the term, aiming at development of internationally active scientists and engineers as human resources that can contribute to global environmental protection, resource exploitation and protection.	2001	Social problem
Health/medical care	Development of an HIV vaccine	2003	Technical difficulty
Elementary particles	Practical use of a mass storage device that allows writing speeds in excess of 1GB per second.	2004	Technical difficulty
Health/medical care	Wide-spread use of a social system for secondary prevention of cancer (early detection) and enhanced knowledge among the general public make the average 5-year probability of survival of all types of cancers higher than 70% (current value: 50%).	2003	Technical difficulty, social problem, cost and other problems
Elementary particles	Practical use of pattern processing technology in the domain less than 10 nm, where synchrotron orbit radiation (SOR) is used as the light source of lithography.	2004	Cost and other problems
Communication	Establishment of an international ISDN network covering almost every country, enabling automatic connection to these countries from the ISDN network in Japan.	2004	Advent of alternative technology
Elementary particles	Practical use of an analytical instrument capable of ultra-low concentration analysis down to ppt [10^{-12}] level.	2004	Low needs
Materials and processes	Practical use of large-area, high conversion efficiency (>20%) amorphous solar cells.	2004	Technical difficulty
Life science	Practical use of therapeutic methods that prevent cancer metastasis.	2007	Technical difficulty
Production	Extensive use of room-temperature superconductive materials in industrial products.	2008	Technical difficulty
Energy	Practical use of disposal technology for solidified high-level nuclear waste.	2009	Social problem
Information and electronics	Advancement in verification technology leads to the rapid development of large-scale software and the elimination of errors.	2009	Technical difficulty

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4-1 Examples of Realized Topics

(1) Provision of Services through a Network

The provision of a variety of services through a network, such as information exchange, transport and accommodation reservations, and purchasing goods — as we see today provided by the Internet — were given in every survey. The term "Internet," as a matter of course, was not mentioned, but many of the desirable concepts were already introduced.

(2) Emergency Medical System

The topics related to the emergency medical system provided important themes from the early surveys, and, by and large, many of these have already been realized in Japan. Nevertheless, a topic directly related to this issue is still given in the ninth survey (".A flexible regional healthcare system capable of corrective modification, coping with regional differences, especially in terms of emergency medical care"), and it is predicted to be realized in 2021. A reemergence of similar themes as new topics of importance may well be expected as the established system gradually becomes inadequate in view of changing social situations.

(3) Cloning Technology of Somatic Cells

The term "cloned animal" became widely used by 1982. Actually, the first success in cloning from somatic cells, a cloned sheep named Dolly, was announced in February 1997, which somewhat preceded the experts' forecast. In the sixth survey (1997), the questionnaire was conducted just before the above announcement, and the experts predicted 2015 as the year when the "realization of cloning technology from a somatic cell of livestock" would occur.

The Delphi survey, because of its fundamental nature of consolidating a variety of opinions in a

direction and giving survey results as a median estimate, has a weakness in that it may fail to reflect the prescient opinions of the minority, making it difficult to predict when and how a breakthrough technology will be realized. This is a typical case where this weakness was made visible.

4-2 Examples of Unrealized Topics

(1) Prevention of Carcinoma Metastasis

Owing to the advancement of diagnostic techniques, early detection and prompt therapy became feasible for certain types of cancer. However, although the mechanism that gives rise to malignant alteration of cancer is steadily becoming clear, a method to prevent carcinoma metastasis has not been developed and remains a topic of great concern even now. The time scope of the forecast set by each survey is normally from 15 to 20 years from the time of the survey, and this topic is one where the expected period of realization has been postponed every time the survey is conducted. The development of a drug that prevents carcinoma metastasis is also given in the ninth survey, and the prediction is that the technique will be established by 2023 and enter into general clinical application by 2032.

Table 4 : Topics Associated with Network Service

Survey No. (year)	Topics	Predicted year of realization
1st survey (1971)	Direct access to overseas databanks will become feasible, enabling direct data transaction with them.	1987
1st survey (1971)	Implementation of a world-wide network for transport/accomodation reservations (limited to large hotels in large cities and holiday resorts), and the establishment of a global real-time system.	1980
2nd survey (1977)	Establishment of an information guidance system using visual (bi-directional) communication enables the provision of a variety of information for enhanced convenience of daily life, and enables rich and varied life planning.	1987
3rd survey (1982)	Implementation of the international data communication network, covering almost every country, enables direct connection from Japan's domestic data communication network.	1994
4th survey (1987)	Leasing orders and a second-hand goods exchange system come into widespread use at the nation-wide level.	1994
5th survey (1992)	Widespread use of the communication system that enables search and browsing of static/ dynamic images from an electronic library (textual information, books, static images, movies, television, documentary video library)	2005
5th survey (1992)	Practical use of an artificial reality computer network that enables geographically distant members of the general public to share a virtual space.	2005

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Table 5 : Examples of Topics Related to the Emergency Medical System

Survey No. (year)	Topics	Predicted year of realization
1st survey (1971)	Nation-wide completion of the network for emergency medical service, and establishment of an emergency conveyance system enabling rapid delivery of patients to the appropriate medical facility.	1986
2nd survey (1977)	Same as above.	1990
3rd survey (1982)	Establishment of a nation-wide emergency medical service system that provides appropriate medical service regardless of the geographical location of the patient: combination of well-placed local emergency centers under the control of the central medical center where all the data is diagnosed.	1997
5th survey (1992)	Widespread implementation of close communication between ambulances and hospitals (e.g. information from an image and knowledge database for emergency treatment).	2003

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Table 6 : Examples of Topics Related to Cloning Technology

Survey No. (year)	Topics	Predicted year of realization
1st survey (1971)	The development of an asexual reproduction technique for genetically homogeneous experimental animals, based on the tissue culture of somatic cells.	2000
3rd survey (1982)	Widespread use of reproduction techniques (including cloning) to produce experimental animals.	1999
5th survey (1992)	Development of techniques to grow an individual from an embryotic stem cell (a germinative cell at its very early stage).	2011

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(2) Large-area, High-efficiency Solar Cell

The solar cell, especially its conversion efficiency, area enlargement, and materials, has been one of the focuses since the first survey, and was expected to yield practical applications by the early 2000s. Area enlargement and efficiency improvement of the solar cell ("Large-area, High-efficiency Amorphous Solar Cells") has been a topic in the material-related field, and has been given consecutively from the fourth (1987) to the eighth (2005) survey. This topic was assessed as "unrealized" at the time of the ninth survey. In the ninth survey, this topic is given under the title, "low-cost, large-area, thin-film solar cells with a conversion efficiency of 20% or higher" — note that the material is not specified. The forecast is that this technology will be established by 2019, and will enter into general use in society by 2027.

(3) Traffic Control System

A road traffic control system has also been given as a topic target since the first survey, and yet it has not been realized to this day. This is another example of topics that have experienced postponement from one survey to the next. However, the perspective from which the topic is viewed is gradually shifting: the main theme given in the seventh and preceding surveys (2001) was the determination of traffic volume and a system to control traffic flow, while in the eighth survey (2005) the focus shifted to the construction of a traffic demand management system that optimizes traffic flow in a comprehensive way, paying due attention to response from users. In the ninth survey, individual themes are given as the topics, such as the synchronization of traffic signals with engine control, working at home, and the enhanced utilization efficiency of expressways through the introduction of automatic driving.

4-3 Examples of Topics That Failed to Be Realized due to Reasons Other than Technical Difficulties

For the topics that have failed to be realized, the obstacles are classified into several categories (i.e. technical, social, cost and budgetary, the advent of alternative technology, and low needs) and shown in Figure 2. Table 10 shows the topics that failed to be realized due to reasons other than technical difficulties. Among these, those that failed to be realized because of "low needs" tended to have lower levels of importance than others at the time of the survey, indicating that they might have originally had limited importance.

Table 7 : Examples of Topics Related to the Prevention of Cancer Metastasis

Survey No. (year)	Topics	Predicted year of realization
2nd survey (1977)	Practical use of techniques that prevent cancer cell matastasis.	1993
3rd survey (1982)	Development of effective measures against cancer metastasis.	1999/2003*
4th survey (1987)	Same as above	2002/2005*
5th survey (1992)	Practical use of effective measures against cancer matastasis.	2007/2011*

* The survey gave two different years for realization because the same topics were was placed in two fields (medicine and life science).

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Table 8 : Examples of Topics Related to Large-area, Thin-film Solar Cells

Survey No. (year)	Topics	Predicted year of realization
1st survey (1971)	Solar cell materials with a conversion factor higher than 20% will be developed.	1984 (realized)
2nd survey (1977)	Solar cell materials with a high conversion factor (>20%) and low price level (1000th of the current level or even lower) will be developed.	1995
3rd survey (1982)	Amorphous silicon solar cells with a conversion factor higher than 8% will be put to practical use.	1990 (realized)
4th survey (1987)	Large-area amorphous silicon solar cells with a conversion factor higher than 20% will be put to practical use.	1998
5th survey (1992)	Same as above	2004

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Table 9 : Examples of Topics Related to a Traffic Control System

Survey No. (year)	Topics	Predicted year of realization
1st survey (1971)	A comprehensive traffic control system that enables uniform and smooth traffic flow by integrating such techniques as 2D control and route navigation will be established for major metropolitan areas (e.g. with populations larger than one million)	1983
2nd survey (1977)	Same as above	1996
3rd survey (1982)	A comprehensive traffic control system that enables uniform and smooth automotive-centric traffic flow by integrating such techniques as 2D control and route navigation will be widely used in medium to large urban areas (e.g. with populations larger than half a million).	1997 (Partially realized)
4th survey (1987)	Widespread use of a road traffic control system capable of keeping track of the traffic situation (the types and number of automobiles, flow density, etc.) and providing optimum control in urban areas.	1998
5th survey (1992)	Same as above	2003

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Table 10 : Examples of Unrealized Topics: Classified by the Reasons for No Realization

Reason	Topics	Survey No. (year)	Predicted year of realization
Social problem	Advancement of urban planning technology realizes a showcase of a large metropolitan area (with a population of around one million) where workplaces are well dispersed, resulting in an environment with a high-level of home-workplace mixing.	2nd survey (1977)	1998
	Around one percent of construction costs of public buildings in Japan will be used for additional cultural value: aesthetic appearance and harmony with the surrounding cityscape.	4th survey (1987)	2000
	Organ transplantation (kidney, heart, liver, etc.) will be performed more often, approaching the current level in Europe and the United States.	5th survey (1992)	2001
	Evaluation/utilization standard regarding the use of useful living objects created by biotechnology (genetic modification) in the open environment will be established. Living objects with useful characteristics for environmental purification will be put into practical use.	5th survey (1992)	2006
Cost	Advancement in oil substitution plant technology (development, improvement, and culture method) will lay the technical foundation for the widespread use of alternative energy (overseas products included)	4th survey (1987)	2011
	Advancement in deepsea mineral resource research (manganese, hydrothermal minerals, cobalt, and crust) will enable economic and selective practical mining of these resources.	5th survey (1992)	2006
	Power generation using the coal gasification hybrid cycle will be practically applicable.	5th survey (1992)	2005
	A variable wavelength, free-electorn laser will become widely used in medical applications.	5th survey (1992)	2007
Advent of alternative technology	Millimetric-wave wireless PCM (80-120GHz band) will become practically applicable.	2nd survey (1977)	1990
	Optical card memory with a capacity larger than 10 giga-bits will become widely used (i.e. for digital books).	4th survey (1987)	1997
	High-speed, wide-band switching equipment for multiplexing and time division switching of high-speed, wide band information will become practically applicable.	4th survey (1987)	1993
	An automobile navigation instrument that uses an optical fiber gyrocompass will become widely used.	5th survey (1992)	2004
Low needs	Major parts of software (including general-purpose systems) will be incorporated into hardware (i.e. they become firmware).	2nd survey (1977)	1991
	To make computers even easier to use, voice-input programming technology will become practically usable.	2nd survey (1977)	1996
	Improved rice growth technology will become widely used, enabling rice yields 1.5 times larger per unit area.	3rd survey (1982)	1998
	Electronic newspapers (through satelite/terrestial broadcasting) will become widely used (subscription will be protected by scrambling).	4th survey (1987)	2001

* Most of the topics that failed realization were taken up in more than one survey. The table shown above shows data from the latest surveys (1st to 5th).

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5 Areas of Science and Technology That Seem to Be Realized Earlier than Expected

A look at the assessment of the topics given in the past surveys (from the 1st to 5th), conducted twenty years after the predictions, reveals that twenty to thirty percent of the topics that were forecast to be realized at a time later than the assessment have already been evaluated as "realized" (including partial realization). These are examples of the topics that were realized earlier than expected.

Among the topics given in the fifth survey, an assessment made nearly twenty years later (toward the end of 2009) pointed out that thirteen topics were realized more than five years earlier than expected, and they are shown in Table 11. Nine of them are topics related to the life science or health care/ medicine fields, including such areas as the brain and neuroscience, regenerative medicine, and gene therapy.

The topics in the life science and health/medicine fields have been assigned a relatively long period for realization in every survey. Therefore, the same or similar topics have often been given in multiple surveys and the domains of topics often overlap. Noteworthy here, however, is the fact that nearly half of the topics that were forecast to not be realized by the time of the assessment have actually been realized (or, partially realized).

Figure 3 summarizes the realization status of the topics that were forecast in the fifth survey to take a long period of time. In the life science field, there were 46 topics that were forecast to be realized later than 2010, accounting for nearly half of all topics in the field. Actually, 29 of these topics were assessed as realized (or partially realized) as of the end of 2009. In contrast, in the energy and space fields, where many of the topics are also expected to take a long period of time before realization, only one or two topics have come to fruition earlier than predicted .

Life science and related areas are considered to have a wide global scope for breakthroughs in the days ahead, and one of the weaknesses of the Delphi survey lies in its general unsuitability to predict discontinuous advancements. Life science and health/medicine are considered to be areas with clear, long-term objectives that are less prone to modification over time. These indicate the risk of such simple, stereotyped thinking that, "it must require a long period of time before realization."

6 Conclusion

In Delphi surveys, incompatible technologies are sometimes given as future options, and even a topic that seems to challenge others may be given to probe future direction. The fact that nearly seventy percent of the topics including those seemingly challenging cases, have been realized in one way or another reveals the significance of the uninterrupted implementation of Delphi surveys and the reliability of a certain amount of the results, as well as the surveys' substantial value as an intellectual asset. It should be noted, however, that the major results from a Delphi survey may have ignored minority opinions, and there may remain important technologies that have escaped the attention of the survey.

A glimpse into the views and insights of the experts in the past also encourages us to ask ourselves if we have the same level of insight as they did. Perhaps we have to consider by ourselves if we have a power of prediction now that will be highly appreciated by experts in the future.

Table 11 : Examples of Topics That Were Assessed to Have Been Realized more than Five Years Earlier than Expected
(The forecasts given in the 5th survey [1992] were assessed at the time of the 9th survey [toward the end of 2009])

Field	Topic	Predicted year of realization	Realization status at the end of 2009
Life Science	An interface directly connecting the brain and a computer will be developed.	2020	Partially realized
Life Science	Technology for artificial cell synthesis, for replacing some of the functions of natural cells, will be developed.	2019	Partially realized
Life Science	The link between the thought process and the neuron activities inside the brain will be clarified.	2018	Partially realized
Life Science	Artificial intelligence technology that mimicks the thought process in the brain will be developed.	2017	Partially realized
Life Science	The neurobiological foundation underlying human emotion will be clarified.	2017	Partially realized
Health/Medical Care	Techniques for artificial preparation (excluding fetus cells) and transplantation of a cell that can grow and provide an organ function will be developed (e.g., as a therapeutic method for Alzheimer disease).	2020	Partially realized
Health/Medical Care	Electric circuitry directly connectable to neuro/brain cells will be developed and applied in an artificial eyesight system.	2019	Partially realized
Health/Medical Care	The mechanism of individual aging will be clarified, and the knowledge will be applied to anti-aging therapy.	2018	Partially realized
Health/Medical Care	Gene therapy will become practically applicable to many gene-defect diseases.	2016	Partially realized
Space	Space tourism around the earth on board a spaceship will become available.	2016	Partially realized
Marine and Earth	Combined efforts of humans — technological advancement of natural energy ulitization, the reduction of man-made heat generation, and the suppression of heat accumulation in the atomosphare — will facilitate a balance in the heat budget of the earth.	2016	Partially realized
Mineral/Water Resources	Technology for artifical precipitation (in case of drought) will become practically applicable.	2015	Partially realized
Environment	The presence or absence of persistent effects of environmental pollution on humans (i.e., inherited from one generation to the next) will be clarified.	2015	Partially realized

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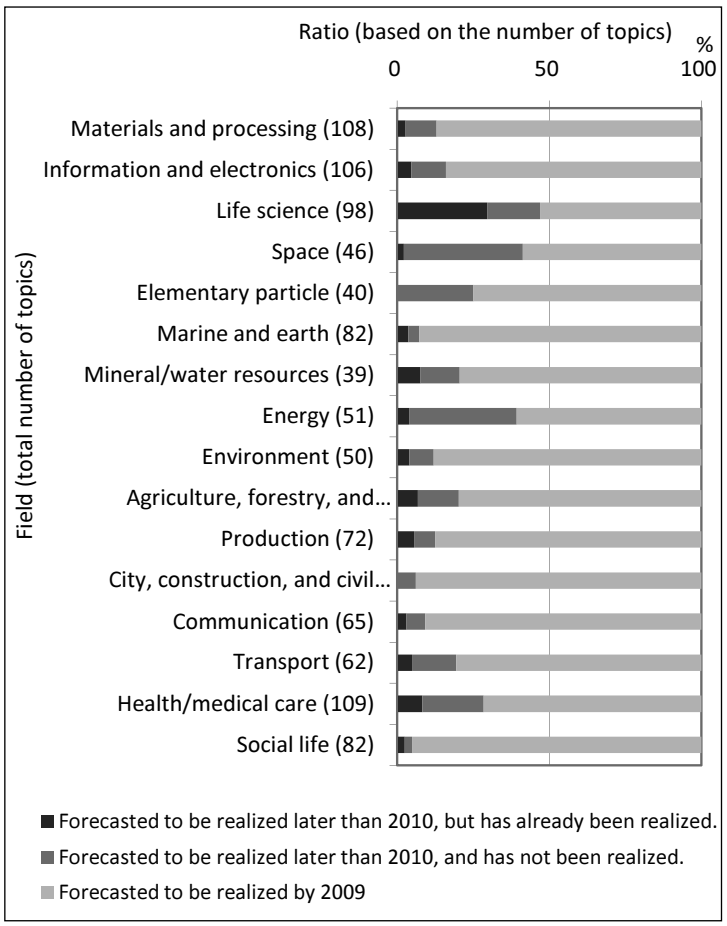

Figure 3 : Realization Status of Topics in Science and Technology That Were Forecasted to Take a Long Period of Time before Fruition

(The forecasts given in the 5th survey [1992] were assessed at the time of the 9th survey [toward the end of 2009])

Prepared by the SFTC

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* For the realization status assessment of past Delphi surveys, see "The 9th Delphi Survey."

[2] Past Delphi surveys:
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Profile

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